VOLTAGE DETECTION CIRCUIT

[0001]   This application is based on Japanese Patent Application No. 2003-.099185 filed on April 2, 2003, the contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002]   The present invention relates to a voltage detection circuit for checking whether an input voltage is equal to a predetermined level or not.

Description of the Prior Art

[0003]   Fig. 4 shows an example of the configuration of a conventional voltage detection circuit.   In the voltage detection circuit shown in Fig. 4, when the voltage V_{CC} applied to an input terminal 5 is higher than a predetermined level V_{sh}, the voltage outputted from a terminal 4 is equal to the voltage V_{CC}; when the voltage V_{CC} applied to the input terminal 5 is lower than the predetermined level V_{sh}, the voltage outputted from the terminal 4 is equal to zero.   Moreover, in the voltage detection circuit shown in Fig. 4, the voltage division factor of the voltage division circuit composed of resistors r1 to r3 and a diode-connected transistor Tr1, the base-emitter voltage of a transistor Tr4, the base-emitter voltage of a transistor Tr5, the resistance of a resistor r4, and the resistance of a resistor r5 are so set that the temperature coefficient of the predetermined level V_{sh} is equal to zero. Incidentally, the voltage detection circuit shown in Fig. 4 is disclosed in Japanese Patent Registered No. 3218641.

[0004]   As described above, in the voltage detection circuit shown in Fig. 4, the voltage division factor of the voltage division circuit composed of the resistors r1 to r3 and the diode-connected transistor Tr1, the base-emitter voltage of the transistor Tr4, the base-emitter voltage of the transistor Tr5, the resistance of the resistor r4, and the resistance of the resistor r5 are so set that the temperature coefficient of the predetermined level V_{sh} is equal to zero.   This means that the voltage detection circuit shown in Fig. 4 is absolutely required to be provided with the resistors r1 to r3, the transistor Tr1, the transistor Tr4, the transistor Tr5, the resistor r4, and the resistor r5.

[0005]   As a result, the voltage detection circuit shown in Fig. 4, in which the temperature coefficient of the predetermined level V_{sh} used as the reference level for voltage detection can be made equal to zero, requires a larger number of circuit elements than a voltage detection circuit in which the reference level for voltage detection varies with temperature.   Since an increase in the number of circuit elements constituting a circuit hampers its cost reduction and miniaturization, it is desirable to minimize such an increase in the number of circuit elements used. However, the voltage detection circuit shown in Fig. 4 is not composed of the minimum needed number of circuit elements.

SUMMARY OF THE INVENTION

[0006]   An object of the present invention is to provide a voltage detection circuit that can be composed of the minimum needed number of circuit elements and that permits the temperature characteristic of the reference level for voltage detection to be set arbitrarily.

[0007]   To achieve the above object, according to the present invention, a voltage detection circuit is provided with: a first transistor and a second transistor that have the emitters thereof connected together to form a differential pair; a voltage division circuit that divides the input voltage into a first division voltage and a second division voltage, that is connected directly to the base of the first transistor to apply the first division voltage thereto, and that is connected directly to the base of the second transistor to apply the second division voltage thereto; and a resistor that has one end thereof connected to the base of the second transistor and that has the other end thereof connected to the emitter of the second transistor. Here, whether the input voltage is equal to a predetermined level or not is checked based on the output from the differential pair.

[0008]   With this configuration, the temperature characteristic of the predetermined level (the reference level for voltage detection) can be set arbitrarily by appropriately setting the voltage division factor of the voltage division circuit, the base-emitter voltage of the first transistor, the base-emitter voltage of the second transistor, and the resistance of the resistor that has one end thereof connected to the base of the second transistor and that has the other end thereof connected to the emitter of the second transistor. Moreover, since the voltage division circuit is connected directly to the base of the first transistor and to the base of the second transistor, the voltage detection circuit can be composed of the minimum needed number of circuit elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]   This and other objects and features of the present invention will become

clear from the following description, taken in conjunction with the preferred embodiments with reference to the accompanying drawings in which:

Fig. 1 is a diagram showing an example of the configuration of a voltage detection circuit embodying the invention;

Fig. 2 is a perspective view schematically showing a section of the structure of an NPN-type transistor;

Fig. 3 is a perspective view schematically showing a section of the structure of a PNP-type transistor; and

Fig. 4 is a diagram showing an example of the configuration of a conventional voltage detection circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010]   Fig. 1 shows an example of the configuration of a voltage detection circuit embodying the invention.   The voltage detection circuit shown in Fig. 1 is composed of an input terminal 1, a constant current source 2, an output terminal 3, PNP-type transistors Q1 to Q3, NPN-type transistors Q4 to Q6, and resistors R1 to R4.

[0011]   The input terminal 1 is connected to the emitter of the transistor Q3, and is also connected through the constant current source 2 to the emitter of the transistor Q1 and to the emitter of the transistor Q2.   The collector of the transistor Q3 is connected, through a serial circuit composed of the resistors R1 to R3, to ground.   The collector and base of the transistor Q3 are short-circuited together.

[0012]   The base of the transistor Q1 is connected directly to the node at which the resistors R1 and R2 are connected together, and the base of the transistor Q2 is connected directly to the node at which the resistors R2 and R3 are connected together.   The emitter and base of the transistor Q2 are connected together through the resistor R4.

[0013]   The collector of the transistor Q1 is connected to the collector of the transistor Q4 and to the base of the transistor Q6, and the collector of the transistor Q2 is connected to the collector of the transistor Q5.   The collector and base of the transistor Q5 is short-circuited together, and the base of the transistor Q4 and the base of the transistor Q5 are connected together.   The emitter of the transistor Q4 and the emitter of the transistor Q5 are connected together and are connected to ground.

[0014]   The collector of the transistor Q6 is connected to the output terminal 3, and the emitter of the transistor Q6 is connected to ground.

[0015]   Configured as described above, the voltage detection circuit shown in Fig. 1 operates as follows.   When the voltage applied to the input terminal 1 is lower than a threshold level V_s, the potential difference across the resistor R2 is so low that the transistor Q1 is kept on and the transistor Q2 is kept off.   This keeps the transistor Q6 on, and thus the output terminal 3 is kept at the ground potential. By contrast, when the voltage applied to the input terminal 1 is higher than the threshold level V_s, the potential difference across the resistor R2 is so high that both the transistors Q1 and Q2 are kept on.   This keeps the transistor Q6 off, and

thus the output terminal 3 is kept in an open state. In this operation of the voltage detection circuit shown in Fig. 1, the threshold level V_S serves as a reference level for voltage detection.

[0016]   Next, a description will be given of the temperature characteristic of the threshold level V_S, i.e., the reference level for voltage detection. Here, let the difference between the base-emitter voltage of the transistor Q1 and the base-emitter voltage of the transistor Q2 as observed when the collector currents of the transistors Q1 and Q2 are in a state of equilibrium be ΔV_{BE}. The voltage ΔV_{BE} is produced by making the emitter current density of the transistor Q1 and the emitter current density of the transistor Q2 different from each other. The emitter current densities of the transistors Q1 and Q2 can be made different, for example, by giving the transistors Q1 and Q2 different emitter areas.

[0017]   Let the base-emitter voltage of the transistor Q3 be V_{F1}, and let the base-emitter voltage of the transistor Q2 be V_{F2}. Let the current that flows through the resistor R2 be I_1, let the current that flows from the node at which the resistor R4 and the base of the transistor Q2 are connected together to the node at which the resistors R2 and R3 are connected together be I_2, and let the resistances of the resistors R1, R2, R3, and R4 be R_1, R_2, R_3, and R_4, respectively.

[0018]   If it is assumed that the base currents of the transistors Q1 and Q2 can be ignored, threshold level V_S, the current I_1, and the current I_2 are given respectively by Equations (1) to (3) below.

$$V_s = V_{F1} + (R_1 + R_2) \cdot I_1 + R_3 \cdot (I_1 + I_2) \tag{1}$$

$$I_1 = \Delta V_{BE} / R_2 \tag{2}$$

$$I_2 = V_{F2} / R_4 \tag{3}$$

[0019] When Equations (1) to (3) are combined together, the threshold level V_s is given by Equation (4) below.

$$V_s = V_{F1} + (R_1 + R_2) \cdot \Delta V_{BE} / R_2 + R_3 \cdot (\Delta V_{BE} / R_2 + V_{F2} / R_4) \tag{4}$$

[0020] When the transistors Q2 and Q3 are given identical characteristics so that their base-emitter voltages V_{F1} and V_{F2}, respectively, are equal, then the equation $V_{F1} = V_{F2} = V_F$ holds. Hence, Equation (4) above can be rearranged to Equation (5) below.

$$V_s = \Delta V_{BE} \cdot \left(\frac{R_1 + R_2 + R_3}{R_2} \right) + V_F \cdot \left(\frac{R_3 + R_4}{R_4} \right) \tag{5}$$

[0021] When Equation (5) above is partially differentiated with respect to the absolute temperature T, Equation (6) below is obtained.

$$\frac{\partial V_s}{\partial T} = \frac{\partial \Delta V_{BE}}{\partial T} \cdot \left(\frac{R_1 + R_2 + R_3}{R_2} \right) + \frac{\partial V_F}{\partial T} \cdot \left(\frac{R_3 + R_4}{R_4} \right) \tag{6}$$

[0022] In Equation (6), the first term of the right side has a positive value, and the second term of the right side has a negative value. Thus, by appropriately setting the base-emitter voltages of the transistors Q1 to Q3 and the resistances R_1

to R_4, it is possible to set the temperature coefficient $\partial V_s / \partial T$ of the threshold level V_S to be any of a positive arbitrary value, a negative arbitrary value, and zero. Normally, the base-emitter voltages of the transistors Q1 to Q3 and the resistances R_1 to R_4 are so set that the temperature coefficient $\partial V_s / \partial T$ of the threshold level V_S is equal to zero. In a case where the circuit that is connected to the voltage detection circuit shown in Fig. 1 has a temperature characteristic, the base-emitter voltages of the transistors Q1 to Q3 and the resistances R_1 to R_4 may be so set that the temperature coefficient $\partial V_s / \partial T$ of the threshold level V_S cancels out the temperature characteristic of that circuit.

[0023] Next, a description will be given of why it is preferable to use PNP-type transistors as the differential pair transistors for voltage detection (i.e., the transistors Q1 and Q2 in Fig. 1) and as the diode-connected transistor provided in the voltage division circuit (i.e., the transistor Q3 in Fig. 1). When an NPN-type transistor is formed in a low-concentration N-type epitaxial layer, it has a vertical structure in which an emitter layer, a baser layer, and a collector layer are vertically arranged as shown in Fig. 2. By contrast, when a PNP-type transistor is formed in a low-concentration N-type epitaxial layer, it has a horizontal structure in which an emitter layer, a baser layer, and a collector layer are horizontally arranged as shown in Fig. 3. In Figs. 2 and 3, the following symbols are used: "B" represents a base contact; "C" represents a collector contact; "E" represents an emitter contact; "N^+" represents a high-concentration N-type diffusion layer; "N^-" represents a low-concentration N-type epitaxial layer; and "P^+" represents a high-concentration P-type diffusion layer.

[0024]   In the NPN-type transistor shown in Fig. 2, since the base layer is a high-concentration P-type diffusion layer, it has a small resistive component.   By contrast, in the PNP-type transistor shown in Fig. 3, since the base layer is a low-concentration N-type epitaxial layer, it has a large resistive component.   Whereas the resistive component in the base layer exhibits a positive temperature characteristic, the base-emitter junction potential exhibits a negative temperature characteristic.   Thus, the temperature-related variation of the base-emitter voltage is smaller in a PNP-type transistor, in which the base layer resistive component is large, than in an NPN-type transistor, in which the base layer resistive component is small.   For this reason, it is easier to set the temperature coefficient of the reference level for voltage detection to be equal to zero when PNP-transistors are used as the differential pair transistors for voltage detection (i.e., the transistors Q1 and Q2 in Fig. 1) and as the diode-connected transistor provided in the voltage division circuit (i.e., the transistor Q3 in Fig. 1) than when NPN-type transistor are used instead.

[0025]   The voltage detection circuit shown in Fig. 1 is typically incorporated in a semiconductor integrated circuit device, which is fabricated through a combination of various processes such as film formation, lithography, etching, and impurity doping.   Here, it is preferable that the resistors R1 to R4 be formed simultaneously by the same process.   By forming the resistors R1 to R4 by the same process, even if the individual resistances R_1 to R_4 deviate from their design values, it is possible to minimize the deviations in the ratios between them (for example R_1 / R_2).   This also helps, as will be clear from Equation (6) noted above,

to minimize the deviation in the temperature coefficient $\partial V_s / \partial T$ of the threshold level V_S from its set value.

[0026]   In the voltage detection circuit shown in Fig. 1, between the input terminal 1 and the resistor R1 is provided the transistor Q3 having the base and collector thereof short-circuited together.   It is, however, also possible to connect the input terminal 1 directly to the resistor R1 and connect the transistor Q3 having the base and collector thereof short-circuited together between the resistors R1 and R2.   It is also possible to use the transistor Q3 as the reference source of a current mirror circuit.   For example, it is possible to use as the constant current source 2 a PNP-type transistor that together with the transistor Q3 forms a current mirror circuit.